CFR Emissions and Test Cycle Requirements: Light Duty Diesel

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In this presentation

Some context and background

- NOx and diesel operation
- Silverado 2500 allegations

Applicable regulations from CFR

- Start with optional chassis certification for Tier 2 HDV
- Focus on emissions and test cycles, not durability or evaporative / refueling emissions testing.
- Which cycles are applicable?
- In general use, what about differences in (a) temperature, (b) altitude, or (c) drive cycles?
- Summary

Literature: Effect of on-road driving

- Drive cycles
- Grade
- Low temperature
- High temperature
- Altitude
- Summary

Gaps between on-road driving and cycle tesing

Context: NOx tradeoffs in diesel systems

Gasoline vehicles use TWC, which require stoichiometric engine operation.

Diesel engines run lean, and require a different aftertreatment methodology. More modern diesels have one or both of:

- SCR (selective catalyst reduction)
  - Tradeoff between engine-out PM and NOx
  - SCR effectiveness is sensitive to NOx concentration
  - DPFs are effective at reducing PM, even at high rates, but high levels of PM contribute to early failure.
  - Manufacturers tend to bias toward lower NOx on-cycle, where SCR is more effective, but lower PM off-cycle.
- LNT (lean NOx trap)
  - Tradeoff between NOx and fuel consumption.
  - LNT requires regeneration with rich atmosphere, which requires extra fuel.
  - More EGR = lower engine-out NOx = fewer regens.
  - But more EGR contribute to lower durability.

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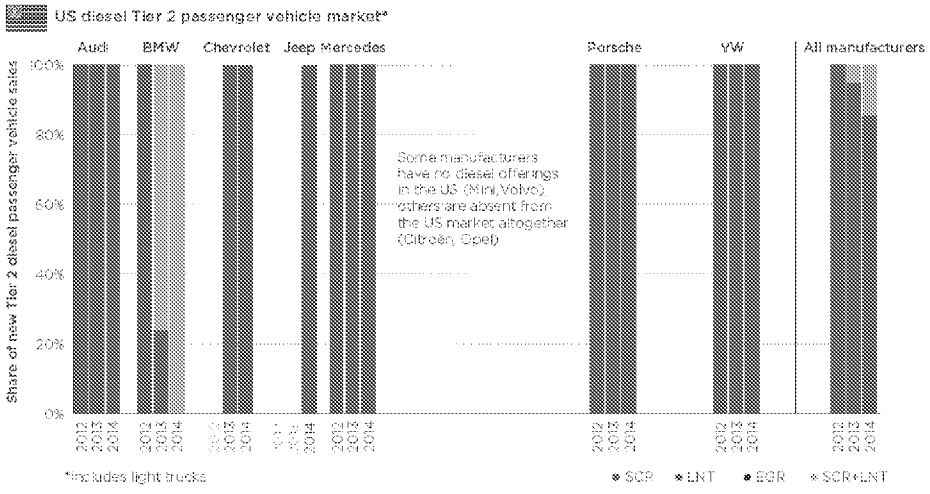
Context: NOx aftertreatment in LD diesel powertrains



VW/Audi engines after-treatment systems contain LNTs; remainder are SCR systems.

Liuhanzi Yang, Vicente Franco, Alex Campestrini, John German, and Peter Mock. (September 2015). *NOx control technologies for Euro 6 Diesel passenger cars: Market penetration and experimental performance assessment*, ICCT White Paper.

Context: Fenner & Herman v. GM (Silverado 2500 NOx Allegations)

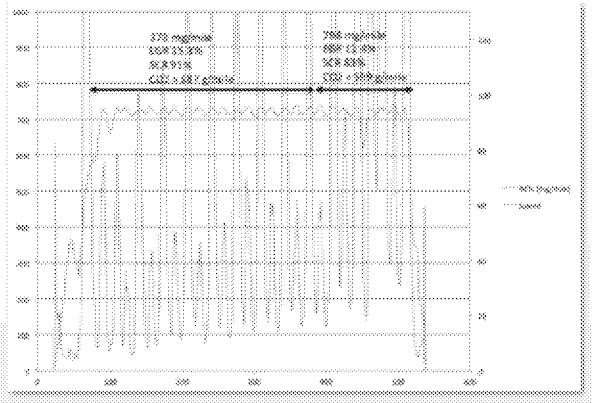
From Class Action Complaint:

Testing conducted indicates that:

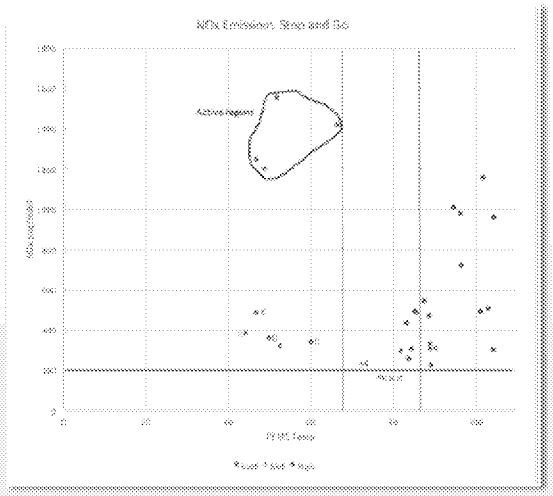
- Silverado and Sierra 2500HD vehicles emit far more pollution on the road than in the emission certification testing environment
- These vehicles exceed federal and state emission standards
- These vehicles and employ at least three different defeat devices that reduce the effectiveness of emissions controls when the vehicle senses that it is not in the certification test cycle:
  - Testing confirmed that the vehicle complies with emissions standards at the temperature windows where the emissions test is performed for certification. But the NOx emissions increase significantly when the temperature is below 68°F or above 86°F.
  - Higher emissions occur after the vehicle has been run for 200-500 seconds of steady speed operation on average by a factor of 4.5 in all temperature windows.

Context: Fenner & Herman v. GM (Silverado 2500 NOx Allegations)

Examples given:



Higher emissions with increasing time



Higher emissions with lower and higher temperature

Tier 2: Optional chassis certification for diesel vehicles.

Blue text are direct quotes from CFR

§ 86.1863–07 Optional chassis certification for diesel vehicles.

- A manufacturer may optionally certify heavy-duty diesel vehicles weighing 14,000 pounds GVWR or less, to the standards specified in § 86.1816– 08.
- Such vehicles must meet all requirements of subpart S of this part that are applicable to Otto-cycle vehicles, except for evaporative, refueling, and OBD requirements where the diesel specific OBD requirements would apply.
- This section does not apply for vehicles certified to the Tier 3 standards in §86.1816-18, including those vehicles that certify to the Tier 3 standards before model year 2018.

Thus, HD complete diesel vehicle = HD complete Otto vehicle (for Tier 2).

Applicability in Subpart S

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§ 86.1801–12 Applicability.

- (a) *Applicability*. Except as otherwise indicated, the provisions of this subpart apply to new light-duty vehicles, light-duty trucks, medium-duty passenger vehicles, and Otto-cycle complete heavy-duty vehicles....
- In cases where a provision applies only to a certain vehicle group based on its model year, vehicle class, motor fuel, engine type, or other distinguishing characteristics, the limited applicability is cited in the appropriate section of this subpart.
- (h) *Applicability of provisions of this subpart to light-duty vehicles, light-duty trucks, medium-duty passenger vehicles, and heavy-duty vehicles*. Numerous sections in this subpart provide requirements or procedures applicable to a ''vehicle'' or ''vehicles.'' Unless otherwise specified or otherwise determined by the Administrator, the term ''vehicle'' or ''vehicles'' in those provisions apply equally to light-duty vehicles (LDVs), light-duty trucks (LDTs), medium- duty passenger vehicles (MDPVs), and heavy-duty vehicles (HDVs), as those terms are defined in § 86.1803–01.

Thus, "vehicle" includes HD complete Otto vehicle (and therefore HD complete diesel vehicle) unless explicitly noted otherwise.

Diversion: Defining test groups

§86.1820-01 Durability group determination.

- This section applies to the grouping of vehicles into durability groups. Manufacturers shall divide their product line into durability groups based on the following criteria...

§86.1827-01 Test group determination.

- This section applies to the grouping of vehicles into test groups within a durability group. The vehicles covered by an application within a durability group shall be divided into test groups based on the following criteria. The manufacturer shall use good engineering judgment in grouping vehicles into test groups....

Thus, all "vehicles" are included in a "test group."

Emission testing requirements: FTP & SFTP (to 2014)

EDV = emissions demonstration vehicle

§ 86.1829–01 Durability and emission testing requirements

- *Testing at low altitude.* One EDV shall be tested in each test group for exhaust emissions using the FTP and SFTP test procedures of subpart B of this part and the HFET test procedure of subpart B of part 600 of this chapter.
- *Testing at high altitude.* the manufacturer can either:
  A. Test one EDV in each test group for exhaust emissions using the FTP test procedures of subpart B of this part; or
  B. ...provide a statement in its application for certification that, based on the manufacturer's engineering evaluation of appropriate high-altitude emission testing, all light-duty vehicles, light-duty trucks, and complete heavy-duty vehicles comply with the emission standards at high altitude.

Thus, one EDV from all test groups are tested over the FTP, SFTP, and HFET. One assumes most manufacturers opt for an engineering evaluation of high altitude performance.

Emission testing requirements: Cold CO/NMHC and Idle CO (to 2014)

§ 86.1829–01 Durability and emission testing requirements

- The manufacturer must test one EDV in each durability group for cold temperature CO and cold temperature NMHC exhaust emission compliance in accordance with the test procedures in subpart C of this part or with alternative procedures approved in advance by the Administrator.
- To determine idle CO emission compliance for light-duty trucks and complete heavy-duty vehicles, the manufacturer shall follow one of the following two procedures:
  A. For test groups containing light-duty trucks and complete heavy-duty vehicles, each EDV shall be tested in accordance with the idle CO testing procedures of subpart B of this part; or
  B. a manufacturer may provide a statement in its application for certification that, based on the manufacturer's engineering evaluation of such idle CO testing as the manufacturer deems appropriate, all light-duty trucks and complete heavy-duty vehicles comply with the idle CO emission standards.

Thus, one EDV from all test groups are tested over the Cold CO cycle. One assumes most manufacturers opt for an engineering evaluation of idle CO.

Emission testing requirements: FTP, SFTP, Cold CO (2015+)

§ 86.1829–15 Durability and emission testing requirements

- The manufacturer must test EDVs as follows to demonstrate compliance with emission standards:
  1) Test one EDV in each durability group using the test procedures in 40 CFR part 1066 to demonstrate compliance with cold temperature CO and NMHC exhaust emission standards.
  2) Test one EDV in each test group using the FTP, SFTP, and HFET test procedures in 40 CFR part 1066 to demonstrate compliance with other exhaust emission standards.
- The above tests are run at low-altitude conditions.
- For standards that apply at high-altitude conditions, the manufacturer may either perform the same tests or provide a statement... that, based on an engineering evaluation of appropriate testing... all vehicles comply with applicable emission standards at high altitude.

Thus, one EDV from all test groups are tested over the cold CO, FTP, SFTP, and HFET. One assumes most manufacturers opt for an engineering evaluation of high altitude performance.

Cycles and emission standards: LDV/LDT/MDPV Tier 2

§86.1811-04 (+09 +10) Emission standards for light-duty vehicles, light-duty trucks and medium-duty passenger vehicles.

Cycle			NOx	NMOG NMHC	CO	HCHO Formaldehyde	PM	N2O CH4 § 86.1818–12
FTP	(c)	LD+MD	X	X	X	X	X	X
SFTP: US06	(f)	LD only		X	X			
SFTP: SC03	(f)	LD only		X	X			
SFTP Weighted	(f)	LD only		X	X		X	
HWFET	(j)	LD+MD	X					
Cold CO (gasoline only)	(g)	LD+MD		X	X			

Thus, Tier 2 emission standards for LDV and LDT depend on all five cycles, but MDPV depends only on FTP, HWFET, and Cold CO.

Cycles and emission standards: LDV/LDT/MDPV Tier 3

§86.1811-17 Exhaust emission standards for light-duty vehicles, light-duty trucks and medium-duty passenger vehicles.

Cycle			NOx	NMOG NMHC	CO	HCHO Formaldehyde	PM	N2O CH4 § 86.1818–12
FTP	(b)	LD+MD	X		X	X	X	X
SFTP: US06	(f)	LD+MD					X	
SFTP: SC03	(f)	LD+MD						
SFTP Weighted	(b)	LD+MD	X		X			
HWFET	(c)	LD+MD	X					
Cold CO (gasoline only)	(g)	LD+MD		X	X			

Thus, for Tier 3, emission standards for LDV and LDT and MDPV depend on all five cycles.

Cycles and emission standards: HDV Tier 2 and Tier 3

§86.1816-05 (+08) Emission standards for complete heavy-duty vehicles.

Tier 2		NOx	NMOG	CO	HCHO Formaldehyde	PM
FTP (presumably)	(a)	X	X	X	X	X
Idle	(g)			X		

§86.1816-18 Emission standards for complete heavy-duty vehicles.

Tier 3		NOx	NMOG	CO	HCHO Formaldehyde	PM
FTP	(b)		X	X	X	X
HD-SFTP: UDDS + SC03 + US06 or US06 HW or LA92	(b)		X	X		X
HWFET	(c)		X			

Thus, for Tier 2, emission standards for HDV certified under subpart S depend only on FTP (n.b., the Tier 2 standards do not actually specify the test procedure), and even for Tier 3 there is no Cold CO requirement.

Altitude effects (1/2)

§86.1803-01 Definitions

- *High altitude* means any elevation over 4,000 feet.
- *High-altitude conditions* means a test altitude of 5,315 feet, plus or minus 328 feet...
- *Low altitude* means any elevation equal to or less than 4,000 feet.
- *Low-altitude conditions* means a test altitude less than 1,800 feet.

§ 86.1810–09 General standards

- All emission standards apply at low altitude conditions and at high altitude conditions, with the following exceptions:
  1) The supplemental exhaust emission standards as described in §86.1811-04(f) apply only at low-altitude conditions;
  2) The cold temperature NMHC emission standards as described in §86.1811-10(g) apply only at low-altitude conditions;
  3) The evaporative emission standards specified in §86.1811-09(e) apply at low-altitude conditions....

Thus, for all vehicles, all applicable standards apply up to 1800 feet.
In addition, FTP, HFET, and cold CO standards apply at 4987 - 5643 feet (but technically not at 1800 – 4987 feet).

Altitude effects (2/2)

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- For vehicles that comply with the cold temperature NMHC standards described in §86.1811-10(g) and the CO2, N2O, and CH4 exhaust emission standards described in §86.1818-12, manufacturers must submit an engineering evaluation indicating that common calibration approaches are utilized at high altitudes (except when there are specific high altitude calibration needs to deviate from low altitude emission control practices).
- [These vehicles are 2012 and later LDV, LDT, and MDPVs.]
- Any deviation from low altitude emission control practices must be included in the auxiliary emission control device (AECD) descriptions submitted at certification.
- Any AECD specific to high altitude must require engineering emission data for EPA evaluation to quantify any emission impact and validity of the AECD.

Thus, common calibrations must apply altitudes > 4000 feet for all non-HDVs.

Defeat devices (1/2)

§ 86.1809–12 Prohibition of defeat devices.

- No new light-duty vehicle, light-duty truck, medium-duty passenger vehicle, or complete heavy-duty vehicle shall be equipped with a defeat device.
- The Administrator may test or require testing on any vehicle at a designated location, using driving cycles and conditions that may reasonably be expected to be encountered in normal operation and use, for the purposes of investigating a potential defeat device.
- The manufacturer must show to the satisfaction of the Administrator that the vehicle design does not incorporate strategies that unnecessarily reduce emission control effectiveness exhibited during the Federal Test Procedure or Supplemental Federal Test Procedure (FTP or SFTP) or the [HFET], or the Air Conditioning Idle Test, when the vehicle is operated under conditions that may reasonably be expected to be encountered in normal operation and use.

Note this is a general prohibition, and applies whether or not actual SFTP, HFET, or AC idle testing is performed or used in certification.

Defeat devices (2/2)

§86.1803-01 Definitions.

- *Auxiliary Emission Control Device* (AECD) means any element of design which senses temperature, vehicle speed, engine RPM, transmission gear, manifold vacuum, or any other parameter for the purpose of activating, modulating, delaying, or deactivating the operation of any part of the emission control system.
- *Defeat device* means an auxiliary emission control device (AECD) that reduces the effectiveness of the emission control system under conditions which may reasonably be expected to be encountered in normal vehicle operation and use, unless:
  1) Such conditions are substantially included in the Federal emission test procedure;
  2) The need for the AECD is justified in terms of protecting the vehicle against damage or accident;
  3) The AECD does not go beyond the requirements of engine starting; or
  4) The AECD applies only for emergency vehicles...

Note these definitions have been constant since A/C 24 in 1972.

Defeat devices and temperature.

§ 86.1809–12 Prohibition of defeat devices.

- Intermediate cold temperature CO guideline: The guideline for CO emission congruity across the intermediate temperature range is the linear interpolation between the CO standard applicable at 25 °F and the CO standard applicable at 68 °F.
- NMHC linear guideline is similar.
- For each test group the manufacturer must submit... an engineering evaluation demonstrating to the satisfaction of the Administrator that a discontinuity in emissions of non-methane organic gases, carbon monoxide, carbon dioxide, oxides of nitrogen, nitrous oxide, methane, and formaldehyde measured on the [FTP] and on the [HFET] does not occur in the temperature range of 20 to 86 °F.
- Note Cold CO is run at 20°F (-7°C) and the SC03 at 95°F (35°C).

Thus CO and NMHC standards at intermediate cold temperatures are by definition linear in the cases where there is a cold standard.
But generally pollutants must have no "discontinuity" over the intermediate temperature range.

Defeat devices guidance.

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VPCD-98-13 (HD Engine)

- The agency believes that the manufacturer is obligated to design and install an emissions control system that functions effectively in the real world, i.e., "in normal operation and use."
- [W]hether an AECD is justified as necessary depends in part on considerations of currently available technology. For example, engine protection would not justify an AECD if the need for engine protection is the result of inadequate design of the engine, when viewed in comparison to currently available technology.
- Discusses altitudes where "Significant parts of this country are at altitudes above this threshold."
- In the summer, many areas of the country experience numerous days where the temperature approaches or exceeds 100 degrees F ambient. EPA believes that vehicle operation at 100 degrees F and above is "normal" and that NOx emission controls can and should be designed to work on the hot summer days when they are needed the most.
- Operation at cooler temperatures is "normal," except for extreme cold temperatures.
- Gives examples of AECDs based on altitude, engine temperature, inlet temperature.

In the HD context, EPA has considered some parameters of "normal operation" experienced within "significant parts of the country." In addition, an inadequately designed engine compared to "currently available technology" is not allowed.

Summarizing

- Optionally chassis certified HD vehicles (e.g., Silverados) must meet all requirements of chassis certification
- **All vehicles must be tested** on FTP, HW, US06, SC03, and Cold CO tests (Tier 2 + Tier 3).
  - **LDV standards:** all five cycles (Tier 2 + Tier 3).
  - **MDPV standards:** FTP, HW, and Cold CO only (Tier 2); all 5 cycles (Tier 3).
  - **HDV standards:** FTP only (Tier 2); FTP + HW + SC03 + US06/LA92 (Tier 3).
- **NUMERICAL STANDARDS**: Which and whether standards are set for each cycle depends on vehicle class & Tier 2/3.
- **OPERATIONAL STANDARDS**: Emission control strategies exhibited on the FTP and SFTP must be maintained under conditions which may reasonably be expected to be encountered in normal vehicle operation and use.
- **ALTITUDE**: Manufacturers must evaluate high altitude operation (Tier 2 + Tier 3).
  - FTP, HW, and Cold CO stds apply at 5315 ft.
  - "Common calibration approaches" must be used at all altitudes.
- **TEMPERATURE:**
  - Emissions should not be discontinuous at cold temperatures (down to 20°F).
  - EPA considers temperatures at 100°F and above normal.

Summarizing

- Testing is required for:

Cycle	Tier 2			Tier 3		
	LDV/LDT	MDPV	HDV	LDV/LDT	MDPV	HDV
FTP	X	X	X	X	X	X
SFTP: US06	X	X	X	X	X	X
SFTP: SC03	X	X	X	X	X	X
HWFET	X	X	X	X	X	X
Cold CO	X	X	X	X	X	X

- Numerical standards are set for:

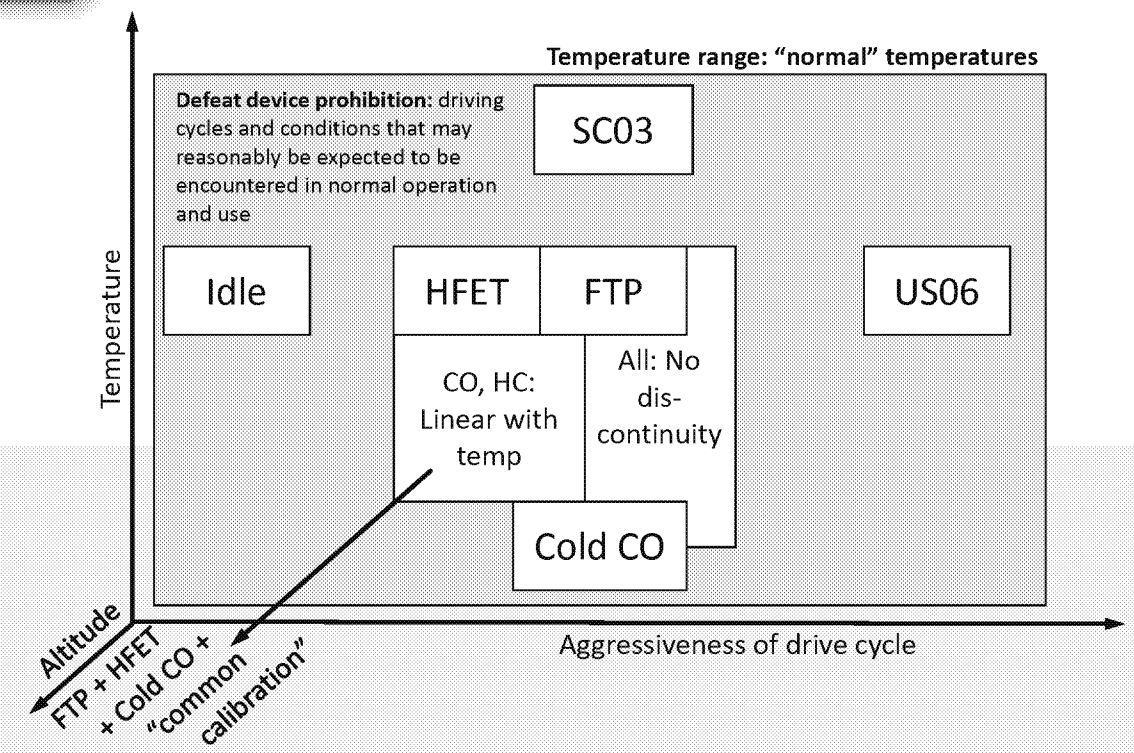
Cycle	Tier 2			Tier 3		
	LDV/LDT	MDPV	HDV	LDV/LDT	MDPV	HDV
FTP	All	All	All	All	All	All
SFTP: US06	NOx HC CO PM			NOx HC CO PM	NOx HC CO PM	NOx HC CO PM
SFTP: SC03	NOx HC CO PM			NOx HC CO PM	NOx HC CO PM	NOx HC CO PM
HWFET	NOx	NOx		NOx HC	NOx HC	NOx HC
Cold CO	HC CO	HC CO		HC CO	HC CO	

Intermediate temperature standards are based on:
- FTP
- HFET
- Sometimes cold CO

Intermediate cycle standards are based on:
- FTP
- HFET
- US06
- SC03

Altitude standards are based on:
- FTP
- HFET
- Cold CO

Coverage of regulations in CFR



Drive cycles v. on-road emissions

Emissions (diesel NOx, specifically) production is a function of:

- Drive cycle characteristics
  - Acceleration and aggressiveness
  - Grade changes
  - Weight of vehicle (i.e. towing?)
- Temperature
- Altitude

Literature review: What really happens as parameters are changed?

Literature: Range of on-road effects

Medium duty commercial vehicle equipped with SCR, tested on-road at nominal temperature and altitude

Emission factor: NOx multiple of reg. cycle	City < 35 kph	Interurban 35-55 kph	Highway 55-60 kph
Base vehicle	1.9	1.6	1.3

On-road parameters changed

Change in on-road NOx due to...	City < 35 kph	Interurban 35-55 kph	Highway 55-60 kph
Running >40°C	+8%	-9%	+8%
Running <15°C		+59%	
High alt. (4700m)	+4%	-	+11%
Reducing GVW	+76%	+53%	+4%

Thus, (a) drive cycle makes a large difference, (b) high ambient temperature moderately increases NOx, (c) low ambient temperature substantially increases NOx, (d) high altitude moderately increases NOx, and (e) higher GVW (in commercial vehicles) reduces NOx (suggestive of towing/hauling in LD).

Betageri, V., & Mahesh, R. (2017). Effects of the Real Driving Conditions on the NOx Emission of a Medium Duty Diesel Commercial Vehicle. SAE Technical Paper No. 2017-26-0124.

Literature: Drive Cycles (FCA)

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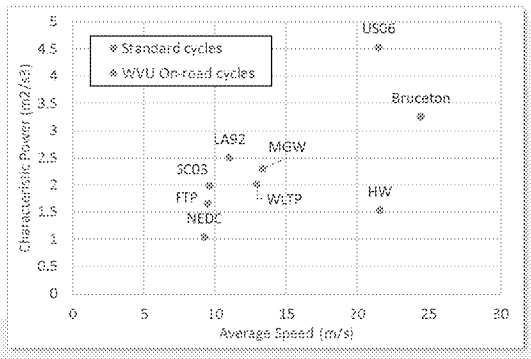
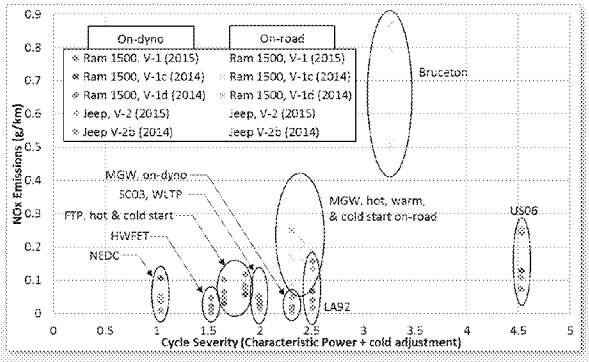
WVU study of FCA Ram and Jeep vehicles looked at dyno and on-road cycles. "Characteristic power" folds together acceleration and grade effects by calculating power required to achieve both.



Cycle characteristics



Test results

Conclusion is that standard cycles have similar operational characteristics as on-road cycles, and more "severe" cycles produce more NOx. However, **these vehicles, when tested on-road, produce more NOx**, even when the same cycle (i.e., MGW) is used.
Thus, **cycle characteristics alone do not explain the discrepancy**.

Besch, M. C., Chalagalla, S. H., & Carder, D. *ON-ROAD AND CHASSIS DYNAMOMETER TESTING OF LIGHT-DUTY DIESEL PASSENGER CARS*.

Literature: Drive Cycles

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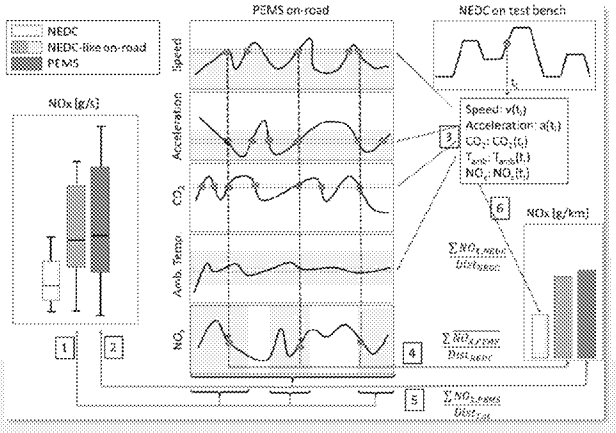
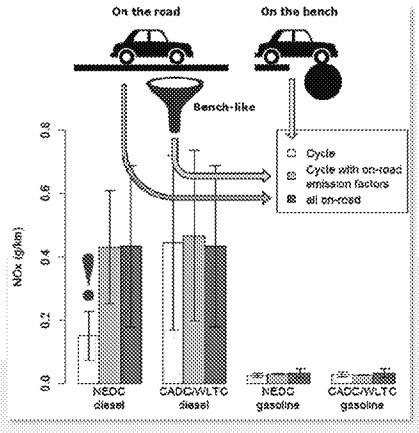
Compares cycle-measured NOx (yellow), on-road NOx (blue), and "constructed" data using cycle speed/load/temp and emissions measured on-road at equivalent points.



Process



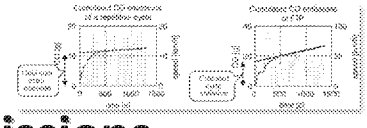
Results

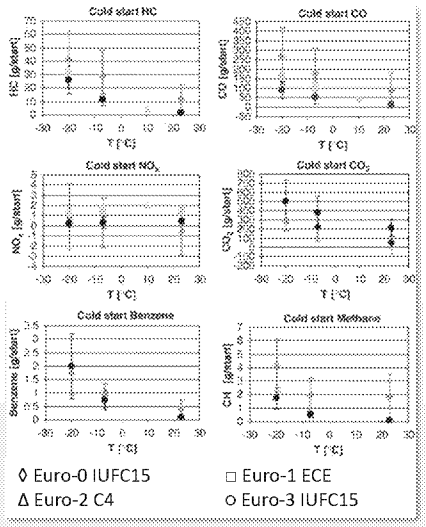
On regulatory NEDC cycle, "constructed" data using on-road NEDC speed/load points matches all on-road data, suggesting **dyno-to-on-road discrepancy is not inherently due to cycle characteristics**.

- For intermediate cold temperatures (10-20°C), the same discrepancy exists.
- But for non-regulatory cycles (CADC, WLTC), the dyno and on-road emissions match.

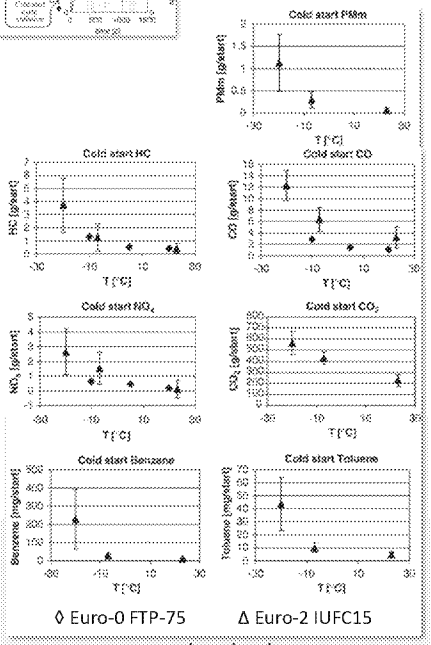
Degraeuwe, B., & Weiss, M. (2017). Does the New European Driving Cycle (NEDC) really fail to capture the NO X emissions of diesel cars in Europe?. *Environmental Pollution*, 222, 234-241.

Literature: Cold start emissions





Gasoline vehicles

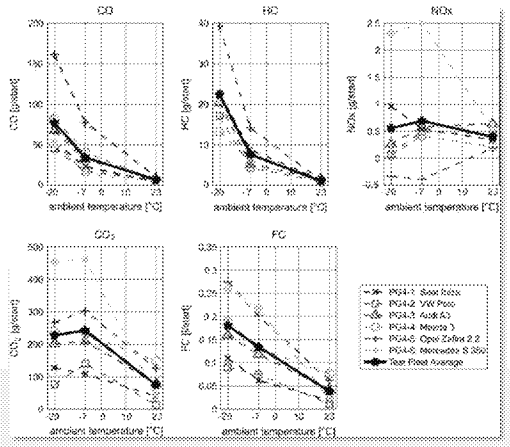


Diesel vehicles

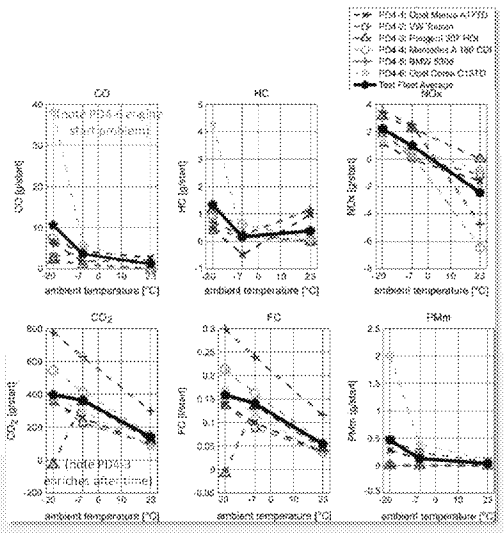
These (c. 1990s) vehicles generally show smooth increases in all emissions with lower temperature. Note gasoline NOx seems insensitive to temperature.

Weilenmann, M., Soltic, P., Saxer, C., Forss, A. M., & Heeb, N. (2005). "Regulated and nonregulated diesel and gasoline cold start emissions at different temperatures." *Atmospheric environment*, 39(13), 2433-2441.

Literature: Cold start emissions



Gasoline Euro-4 vehicles

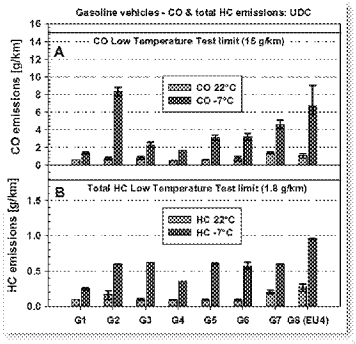


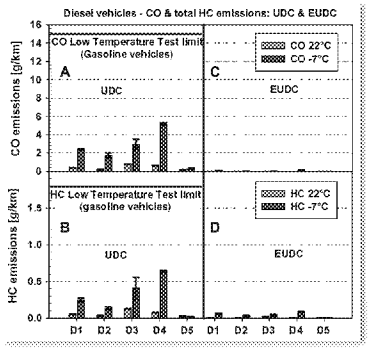
Diesel Euro-4 vehicles

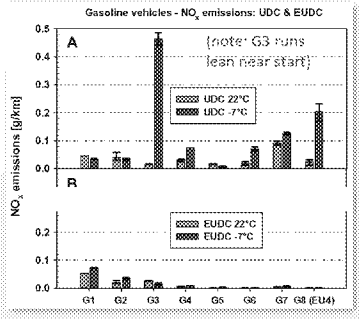
These (c. 2005) vehicles generally show smooth increases in all emissions with lower temperature, with two exceptions: PD4-6 (engine start problem) and PD4-3 (enrichment at cold).

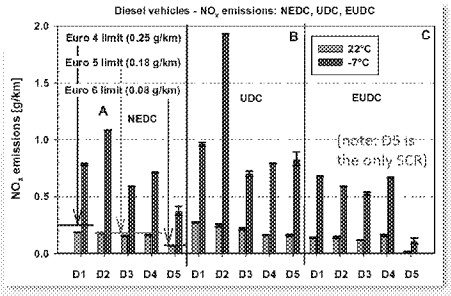
Weilenmann, M., Favez, J. Y., & Alvarez, R. (2009). "Cold-start emissions of modern passenger cars at different low ambient temperatures and their evolution over vehicle legislation categories." *Atmospheric environment*, 43(15), 2419-2429.

Literature: Cold running emissions









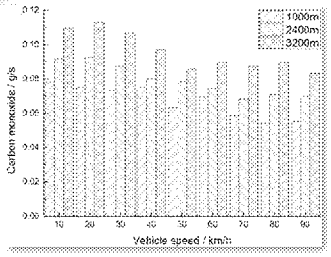
Gasoline Euro-5 vehicles

Diesel Euro-4/5/6 vehicles

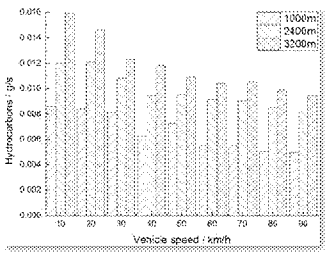
These (c. 2010) vehicles have one outlier: G3 runs lean near start of cycle.
Diesel NOx generally increases by a factor of 3 to 4 at -7°C.

Dardiotis, C., Martini, G., Marotta, A., & Manfredi, U. (2013). "Low-temperature cold-start gaseous emissions of late technology passenger cars." *Applied energy*, 111, 468-478.

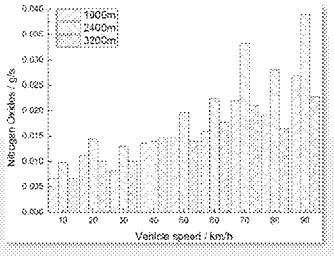
Literature: Altitude



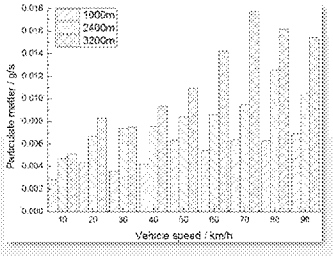
CO



HC



NOx



PM

Single vehicle, no after-treatment (Euro 3)

Driven at three different altitudes

All emissions increase with higher altitude, but NOx shows maximum at 2400m.

Wang, X., Yin, H., Ge, Y., Yu, L., Xu, Z., Yu, C., ... & Liu, H. (2013). On-vehicle emission measurement of a light-duty diesel van at various speeds at high altitude. *Atmospheric environment*, 81, 263-269.

Literature summary

Emissions (diesel NOx, specifically) production

- **Drive Cycle**
  - Aggressive drive cycles produce more NOx.
  - Typical drive cycles may be more aggressive than the FTP, but US06 probably covers the space.
  - However, on-road NOx production does not always match similar cycles in the test cell.
- **Temperature**
  - High temperature does increase NOx, but the effect is small.
  - Low temperature increases NOx more substantially.
  - Emission production tends to smoothly increase with reducing temperature; any exceptions have clear causes (which might warrant looking closer at the vehicle).
  - Some emissions appear to increase quadratically; i.e., production at -20°C is much higher than at -7°C. Is -20°C "normal operation" in significant parts of the country?
- **Altitude**
  - High altitude does increase NOx, but the effect is small (and may be self-canceling).
- **Grade**
  - Grade can be considered as a cycle characteristic; i.e., grade change and acceleration require equivalent engine operation.
- **Vehicle Weight**
  - Increasing in GVW may reduce NOx (unclear if this effect translates to LD/LHD).

Gaps between standards and on-road driving

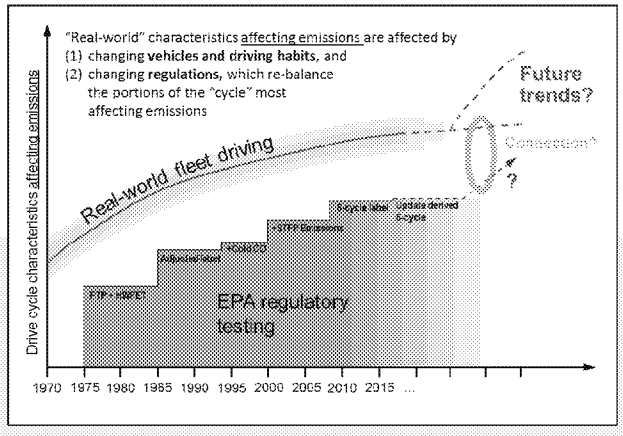
The relative importance of specific "off cycle" operation changes as:

- Standards tighten, reducing emissions on regulatory cycles.
- Vehicle technology and driving patterns shift.

Historically, drive cycle definitions have shifted to close the gap.

"Gaps" could exist due to:

- Vehicle operation / drive cycle characteristics
- Environmental effects (e.g., temperature, altitude, wind)
- Off-cycle loading (e.g. additional elec. loads)
- VMT
- Durability & maintenance
- Vehicles past useful life
- Cheating



But... to what extent are these "conditions which may reasonably be expected to be encountered in normal vehicle operation and use"?